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REVEGETATION OF ACID MINING WASTES IN CENTRAL IDAHO

SURFACE ENVIRONMENT & MINING
SEAM
PROGRAM

USDA Forest Service Research Paper INT-178
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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FRONT COVER PHOTO:

Revegetation research on the Blackbird, a copper-cobalt mine, is being conducted on this 1.1 million cubic yard waste pile. This mine is located on the Salmon National Forest about 25 air miles southwest of Salmon, Idaho. The top of the waste pile is at an elevation of 7,802 feet. Revegetation test plots are located on the south (left) end of the upper bench and on the sloping area at the north (right) end. This waste pile is approximately 20 years old and prior to treatment supported little vegetation because of severe soil acidity and low soil fertility. Treated areas appear as shades of green, white, and light brown. The predominant timber type is lodgepole pine.

INSIDE FRONT COVER PHOTO:

A color infrared oblique photograph of the waste pile shown on the cover. Due to the reflectance of chlorophyll in the infrared spectrum, healthy vegetation appears as shades of red or orange-red. Numbered spots are as follows:

1. *Main test area, installed 1972.*

2. *Hydraulic seeding and hydromulch test plot.*

3. *Test of seeding methods and the addition of soil organic matter.*

4. *Freshly spread topsoil and native subsoils. The darker appearing materials have a greater soil moisture content.*

5. *The only notable invasion of vegetation for 20 years, six lodgepole pine saplings.*

6. *Low-grade ore dump area. See table 4, samples 1 to 5 for typical analyses.*

7. *Coarse rubble slope with spots of high concentrations of metallic salts. See table 4, sample 7, for analysis.*

8. *Phytotoxic concentrations of metallic salts killed the grass along the lower edge of this test area. See table 4, sample 6, for analysis.*

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REVEGETATION OF ACID MINING WASTES IN CENTRAL IDAHO

E. E. Farmer, B. Z. Richardson, and R. W. Brown

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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ABSTRACT

The results of 2 years of revegetation research on acid mining wastes in central Idaho are described. Three types of main plots were used, each containing 12 treatments. Treatments are evaluated in terms of both vegetative production and ground cover. Vegetative species are evaluated in terms of their density and persistence under different treatment conditions. Coupled with a fertilization program, topdressing of mining wastes with selected overburden materials appears to be a highly desirable revegetation practice.

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INTRODUCTION

Acid soils and mine-acid waste and drainage waters are a problem on many mine operations in the Western United States. Erroneously, many people associate mine acid with western coal mining operations. This is understandable because most environmentally aware people have at least heard of the acid problems associated with coal mining in the eastern part of the United States. Usually, western coal mines are situated in alkaline soils. However, western mine-acid problems have the same origin as acid soil and water problems in the East, the oxidation of sulphide minerals. Western mine-acid problems are most often associated with ore production of uranium, lead, copper, cobalt, iron, chromium, platinum, and other metals at relatively high elevations with relatively high average annual precipitation.

One such mine is the Blackbird, a copper-cobalt mine on the Salmon National Forest near Salmon, Idaho. At this mine, elevations range between 6,600 and 8,200 feet. Average annual precipitation ranges from about 25 to 40 inches, with most precipitation falling as snow. The natural vegetation in the area is predominantly lodgepole pine *(Pinus contorta)* with an understory of huckleberry *(Vaccinium* spp.), Oregon grape *(Berberis repens)*, spirea, *(Spiraea* spp.*)*, pinegrass *(Calamagrostis rubescens)*, and some forbs. On disturbed sites such as road cuts the major vegetation is composed of bitterbrush *(Purshia tridentata)*, alder (*Alnus* spp.), rose *(Rosa woodsii)*, bluebunch wheatgrass *(Agropyron spicatum)*, Idaho fescue *(Festuca idahoensis)*, hairgrass *(Deschampsia caespitosa)*, western yarrow *(Achillea millefolium)*, and penstemon forbs and subshrubs *(Penstemon fruticosus)*.

The general physiography of the area is a rugged succession of high ridges with steep hillsides and deep, narrow draws. Although most draws are drained by perennial streams, the smallest draws support streamflow only during periods of active snowmelt, usually May and June. Naturally occurring acidity and concentrations of heavy metals are quite low in streams unaffected by mining. Normal pH of unaffected streams ranges between 6.2 and 6.6 with only trace amounts of metals. However, leachate from mining waste piles or from water flowing from deep mine openings may be of extremely low quality. The pH of these waters may run as low as 2.8 with copper concentration exceeding 100 p/m and iron concentrations of several hundred p/m.

The Blackbird Mining District has a long history. Gold was discovered in 1893 and copper at about the same time. From the late 1890's to the early 1940's ownership of the property changed from time to time and mining was opened and closed several times. No one seemed able to operate a profitable mining venture in the area. During World War II, the Federal Government conducted some exploration for a possible domestic source of cobalt in the area. After the war, private firms continued the exploratory effort and, in 1949, full-scale underground mining for copper and cobalt was started. With the onset of the Korean War, ore production and milling operations were expanded. The Blackbird Mine was active until 1960, but reached its peak production in 1958. It was reopened in 1963 with both a surface pit and an underground operation. All production operations were stopped in late 1967 and, except for exploratory work, the mine has been inactive ever since.

In general, the rocks of the Blackbird District are quartzites and metamorphosed Precambrian sediments. Occasional massive intrusions of chalcopyrite, cobaltite, pyrite, and pyrrhotite occur in mineralized lenses, the first two minerals are high-grade ores, the last two are waste sulphide minerals.

For more than 20 years the Mining District has been a massive contributor of sulphuric acid, copper and iron ions, mine tailings, and erosional products. These mining byproducts have killed all fishes and benthic organisms in Blackbird Creek, the major stream leaving the area. Blackbird Creek is tributary to Panther Creek, which, in turn, is tributary to the Salmon River. Copper ions and sulphuric acid have also eliminated the anadromous fishery in Panther Creek.

This report includes the results of 2 years of revegetation research on an overburden waste dump having a volume of approximately 1,100,000 cubic yards. Research was initiated the summer of 1972 and plantings were made in October of that year. At that time, the waste dump was virtually without vegetation, although it was almost 20 years old. The major long-term objective of this study is to provide several alternative prescriptions for achieving a permanent plant cover on the mining wastes of the Blackbird Mine. We believe the establishment of a permanent plant cover on the dump is prerequisite to reversing the trend away from the production of acid, heavy metal ions, and sediment.

METHODS

The study site is on level overburden material, chosen to avoid complications associated with seed and plant nutrient movement through erosional processes (fig. 1).

Three types of main plots were used: (1) a control plot on overburden material; (2) an irrigated plot on overburden material; and (3) a plot on which the overburden material was topdressed with about 8 inches of soil. These soil materials originated on nearby forest lands at depths ranging to 10 feet. Each main plot consists of 48 subplots, each 8 feet square, that constitute 12 treatments replicated four times. The 12 treatments included three seed mixtures, fertilizer and no fertilizer, and mulch and no mulch (table 1). The fertilizer application consisted of granular 18-46-0 fertilizer at the rate of 435 pounds per acre. Fertilizer was applied on appropriate subplots at planting time and also approximately 1 year later. The mulch application consisted of sphagnum peat moss spread at the rate of 2-1/2 tons per acre and covered with a single layer of jute netting. The three seed mixtures were (1) native species, (2) introduced species, and (3) a mixture of native and introduced species. All seed mixtures were applied at the rate of 25.5 pounds per acre (table 2).

Figure 1.--A general view, looking south, of the upper bench research site immediately after planting, October 1972. Steel rods mark subplot centers.

Table 1.--*Subplot treatments on each of three main plots*

Grass mixture	Fertilizer	Mulch
Native	Yes	Yes
Pasture	Yes	Yes
Native + Pasture	Yes	Yes
Native	Yes	No
Pasture	Yes	No
Native + Pasture	Yes	No
Native	No	Yes
Pasture	No	Yes
Native + Pasture	No	Yes
Native	No	No
Pasture	No	No
Native + Pasture	No	No

Table 2.--*Seed mixtures and seeding rates used in fall planting 1972*

Species		Seeding rate (lb/acre)
	NATIVE SPECIES	
Hairgrass	*Deschampsia caespitosa*	0.75
Bluebunch wheatgrass	*Agropyron spicatum*	3.0
Squirreltail	*Sitanion hystrix*	3.0
Basin wildrye	*Elymus cinereus*	8.25
Cheatgrass	*Bromus tectorum*	1.5
Western wheatgrass	*Agropyron smithii*	3.0
Balsamroot	*Balsamorhiza sagittata*	3.0
Western yarrow	*Achillea millefolium*	0.75
Goldenrod	*Solidago* sp.	2.25
		25.5
	INTRODUCED SPECIES	
Crested wheatgrass	*Agropyron cristatum*	3.0
Intermediate wheatgrass	*Agropyron intermedium*	4.5
Orchardgrass	*Dactylis glomerata*	3.0
Kentucky bluegrass	*Poa pratensis*	1.5
Timothy	*Phleum pratense*	4.5
Smooth brome	*Bromus inermis*	4.5
Meadow foxtail	*Alopecurus pratensis*	1.5
Alta fescue	*Festuca arundinacea*	1.5
Yellow sweetclover	*Melitotus officinalis*	1.5
		25.5
	NATIVE + INTRODUCED SPECIES	
Hairgrass	*Deschampsia caespitosa*	1.5
Timothy	*Phleum pratense*	3.0
Basin wildrye	*Elymus cinereus*	3.0
Orchardgrass	*Dactylis glomerata*	3.0
Intermediate wheatgrass	*Agropyron intermedium*	4.5
Western wheatgrass	*Agropyron smithii*	4.5
Smooth brome	*Bromus inermis*	3.0
Bluebunch wheatgrass	*Agropyron spicatum*	1.5
Crested wheatgrass	*Agropyron cristatum*	1.5
		25.5

Seed of native species was collected by hand and cleaned before being used. Most of the native species used in this work were collected in the vicinity of Cobalt, Idaho. Introduced species were purchased from commercial sources. All species selected for use appeared to have potential for revegetation; all occurred on such disturbances as road cuts and fills in the area.

The soils and overburden materials at the Blackbird Mine are not homogeneous. Spoils and ore-dump areas are especially heterogenous. These materials range from innocuous to highly toxic; most spoils are in the middle of the range, exhibiting low to moderate phytotoxicity. Results of analyses of native topsoils and subsoils used as topdressing and of spoil materials are shown in table 3. Plant-available nitrogen in these samples is negligible. Other areas on the waste dump are severely phytotoxic (table 4). These "hotspots" occupy only a small fraction in the study site and probably represent places where the overburden contained low-grade ores. They range in size from a few to about 10,000 square feet. These areas are particularly difficult to revegetate.

To support vegetative growth, all the overburden materials need lime. Even topdressing soil materials exhibit a lime requirement because of low base saturation. Burnt lime (CaO) was used as the liming agent. Two months before planting, the overburden materials were ripped to a depth of 10 inches and limed at the rate of 800 pounds CaO per acre; the topdressing soil was limed at the rate of 1,600 pounds CaO per acre. The topdressing soil required a greater liming rate than overburden materials because of greater cation exchange capacity. After the lime was spread over the surface, the site was harrowed several times to a depth of about 6 inches. No additional lime was applied during the period covered by this report.

At planting time, the soil materials were harrowed several times. Larger rocks, brought to the surface by harrowing, were removed with a rock rake. During planting, special measures were taken to insure that treatments were applied uniformly and that each was confined to the appropriate subplot area. The fertilizer and seed were separately packaged with silica sand, a carrying agent, and applied by a small seed

Table 3.--*Results of soil and spoil analyses. Samples 1 and 2 are topdressing soil; numbers 3 through 7 are spoil materials*

Sample	pH	Conductivity (µmhos/cm)	Cation exchange capacity (meq/100g)	Percent base saturation	p/m P	p/m K	p/m Cu	Texture
1	6.3	100	6.0	65	2	273	<1	silt loam
2	6.2	100	5.2	58	2	302	<1	silt loam
3	3.6	100	2.2	18	35	420	35	gravelly sand
4	3.5	300	2.1	24	29	428	3	gravelly sand
5	5.1	300	2.6	54	13	88	3	gravelly silt loam
6	4.8	400	2.2	48	14	107	7	gravelly silt loam
7	3.8	800	5.8	26	7	96	22	gravelly silt loam

Table 4.--*Results of overburden analyses on "hotspots," probably low-grade ore dumps. (Except for the pH and conductivity all units are parts per million)*

Sample Number	1	2	3	4	5	6	7
pH Units	3.90	4.10	3.75	3.90	4.00	4.50	4.20
Conductivity µmhos/cm	12,840	5,150	20,040	10,560	3,250	7,260	5,740
Aluminum	26,240	2,250	18,690	24,500	29,980	29,060	39,900
Arsenic	350	160	90	660	650	1,300	60
Barium	90	130	640	130	220	130	60
Boron	10	20	20	40	150	10	40
Cadmium	--	10	--	--	20	--	--
Calcium	1,200	1,130	2,800	2,910	2,250	1,670	500
Chloride	700	50	12,990	21,980	200	1,390	300
Chromium	20	30	50	20	30	30	20
Cyanide	50	--	450	10	10	10	20
Cobalt	280	100	70	500	520	1,110	50
Copper	23,160	26,500	37,400	16,590	7,890	25,510	28,960
Iron	100,570	88,530	68,110	71,590	69,000	94,270	124,410
Lead	30	20	20	30	40	30	20
Magnesium	7,630	6,380	14,550	7,950	1,920	7,190	4,900
Manganese	320	350	250	250	140	210	160
Mercury	--	--	--	10	20	50	20
Nitrate	40	20	20	30	10	10	10
Phosphate	30	1,500	1,330	1,550	1,700	950	900
Potassium	35,820	26,540	19,400	20,450	26,150	27,750	31,400
Selenium	10	10	20	--	30	--	--
Silica	290	300	1,830	150	130	80	60
Silver	--	10	10	--	20	--	30
Sulfate	30,500	29,400	64,970	41,900	1,650	31,500	21,750
Sodium	1,800	1,630	1,730	1,880	2,910	1,900	2,310
Zinc	40	50	60	30	50	80	40

spreader. Rice hulls were used with the seed. Fertilizer was applied and raked in. Then seed was applied and lightly raked. Mulch was applied where appropriate and a Brillion Culti-Packer used to pack the whole area.

From June through September 1973 (the first growing season), water was applied on the irrigated main plot in three weekly applications of one-quarter inch each. From June through September 1974 (the second growing season) water was applied at no set irrigation schedule. Irrigation water was applied "as needed" on the basis of visual observations of plant turgor and length of time since last irrigation or rainfall. Irrigation water was obtained from a nearby creek and hauled to the research site. It was applied through a sprinkler irrigation system with a high degree of uniformity.

Two types of data were collected from each of the 144 subplots: stand density and estimates of the dry-weight herbage production. During data collection, all measurements and counts were made on the interior 6- by 6-foot area of each subplot. In effect, this action separated subplot treatments by a buffer zone 2 feet wide.

Early in the first growing season, grass seedling emergency was assessed by making density estimates on the topdressed plot and on the control plot only. All seedlings were counted on a randomly selected 10-square-foot area of each subplot.

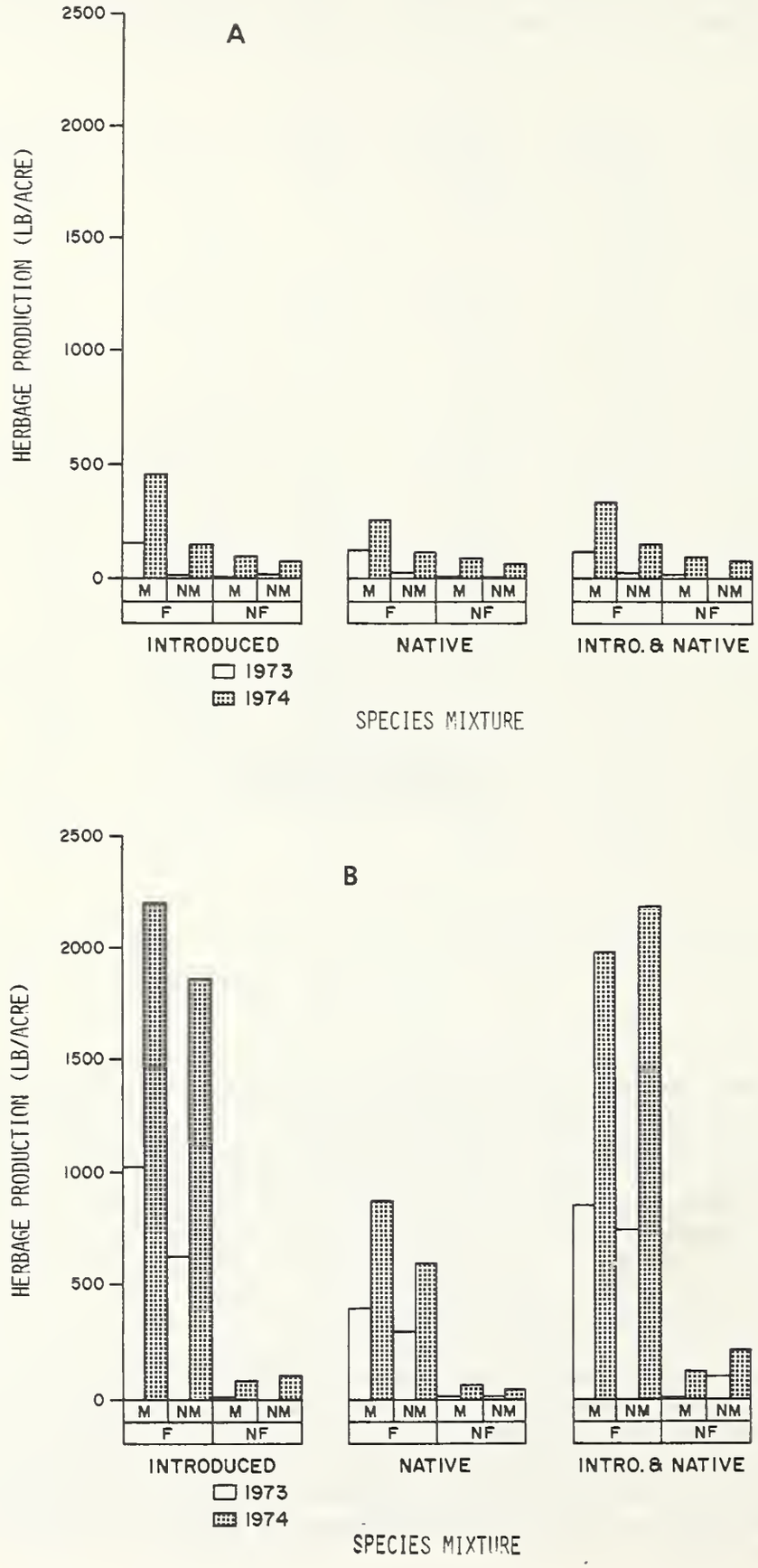
To determine the dry-weight production of vegetation on each subplot, plots were assessed during October 1973 and September 1974. In the assessment work, nondestructive sampling was imperative since future measurements would be required. Therefore, the Neal capacitance meter, model 18-1000, was used to estimate production (Neal and Neal 1973). To calibrate the capacitance meter, one of every six herbage plots read with the meter was clipped, dried, and weighed. Each herbage plot measured 1 by 2 feet.

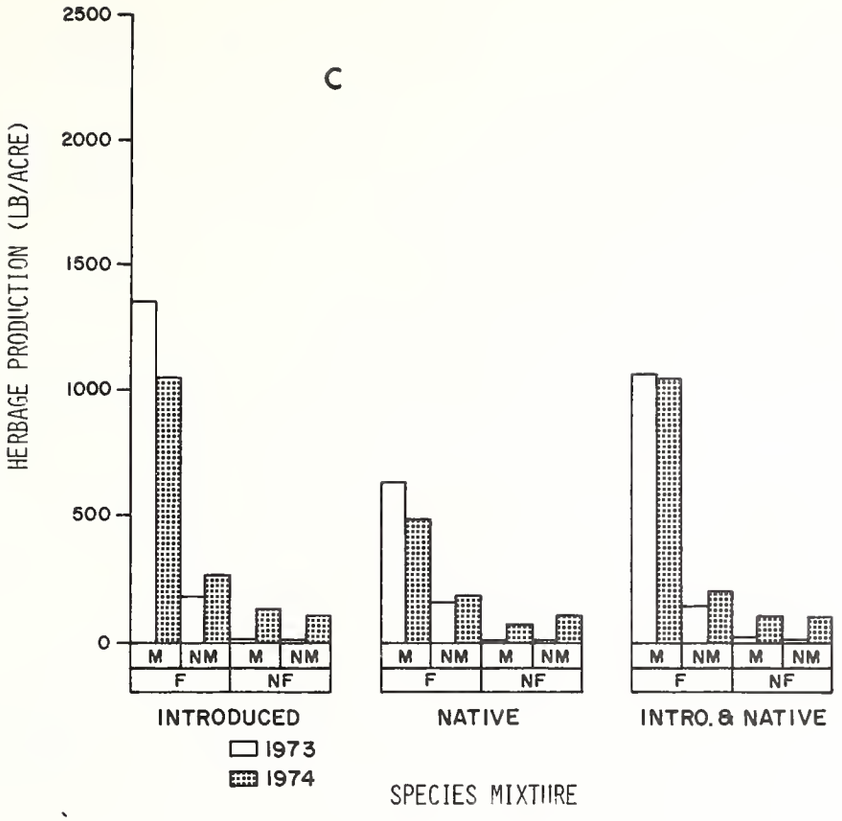
RESULTS

During the two growing seasons reported here, weather conditions were neither unusually severe nor especially favorable. Over the first growing season when the plants were becoming established, the May through August precipitation was about 22 percent below the 10-year mean. However, September precipitation was about 60 percent over the mean. During the second growing season, precipitation for June and July was about 60 percent below the mean, but precipitation for May and August was about 28 percent greater than the mean. Average air temperatures during the first two growing seasons exhibited deviations both above and below the 10-year mean; however, the research area was slightly warmer than normal.

Figure 2 shows the dry-weight vegetative production for the two growing seasons. Generally, the smallest yields have come from the native species and the largest yield from the mixture of introduced grasses. This was the expected result. The native species have performed reasonably well, especially on the topdressed plot. Growth comparisons between 1973 and 1974 generally show a favorable increase during the second growing season. The only exception were the yields of some treatments on the irrigated main plot.

Figure 2.--Average dry-weight vegetative production, Blackbird Mine, compared for 1973 and 1974: A, control main plot, B, topsoil main plot, and C, irrigated main plot.





Data on both seedling emergence and dry-weight production were tested for differences by analyses of variance. The 95 percent probability level was used to determine significant differences. Throughout this paper, 1974 data were used for analyses of variance on dry-weight production. The 1973 data are reported only to point out significant changes between 1973 and 1974. Data on seedling emergence were collected in early spring 1973.

Control Plot

Seedling emergence on the control plot was entirely satisfactory regardless of subplot treatment. Seedling counts ranged from 12 to 38 per square foot; the average was 25 per square foot. The following points describe the effects of seed mixture, mulch, and fertilizer on seedling emergence.

1. Seedling emergence differed significantly due to seed mixtures. The introduced species emerged best ($34/ft^2$), the native + introduced species next ($26/ft^2$), and the native mixture poorest ($14/ft^2$).

2. Mulch caused no significant difference in seedling emergence.

3. The effect of fertilizer on seedling emergence varies with the mulch treatment. Fertilizer had no effect on unmulched plots, but on mulched plots, it significantly increased seedling emergence (21 versus $29/ft^2$).

As expected, the control plot produced less plant material than either of the other main plots (fig. 2A). The stands on the control plot have made large percentage increases in weight during the second growing season, but even the best stands are only marginally acceptable in terms of providing protection against accelerated soil erosion. Without exception, both mulch and fertilizer produced the best stands.

The following points describe the effects of seed mixture, mulch, and fertilizer on dry-weight grass production.

1. Seed mixtures caused no difference in dry-weight production.

2. Mulch significantly increased the production of all mixtures.

3. Mulch and fertilizer interacted significantly--the effect of fertilizer depended on the mulch treatment. On unmulched plots, the positive effect of fertilizer was small (76 vs. 132 lb/acre vegetation). On mulched plots fertilizer has a large positive effect (94 vs. 356 lb/acre vegetation).

Topdressed Plot

Seedling counts on the topdressed plot ranged from 13 to 46 per square foot; the average was 29 per square foot. These counts are high enough to potentially produce good stands of vegetation. The following points describe the effects of seed mixture, mulch, and fertilizer on seedling emergence.

1. Seedling emergence showed a significant difference due to seed mixtures. The introduced species emerged best ($40/ft^2$), the native + introduced species next ($31/ft^2$), and the native mixture poorest ($15/ft^2$).

2. There was a significant difference due to mulch, but the effect varied with species mixture. Mulch decreased the emergence of both the introduced species mixture, and the native + introduced mixture. Mulch had no effect on the emergence of native species.

3. Fertilizer had no effect.

Among main plots, the topdressed plot produced the greatest average yields. At the end of the first growing season (1973), the greatest yields were on the irrigated main plot. However, during the second growing season, the topdressed main plot surpassed the irrigated main plot in vegetative production. Fertilized subplots have given particularly good yields (fig. 2B). The following points result from an analysis of the dry-weight production data:

1. The two seed mixtures that contained introduced grass species produced significantly greater yields than did the native species. However, yields produced by the introduced mixture and the native + introduced mixture were not different from each other.

2. Mulch had no effect on production.

3. Fertilizer increased the production of all species mixtures. Fertilizer benefits were in the following order: introduced species > native + introduced species > native species.

Irrigated Plot

Seedling emergence counts were not made on the irrigated plot. However, limited count data and visual estimates convinced the authors that seedling counts on the irrigated plot would produce results similar to the counts made on the control plot.

During the first growing season, the dry-weight vegetative production on the irrigated plot was greater than on either of the other two main plots. In the second growing season, the irrigated plot did not make much additional growth and the greatest yielding subplots showed a decline in dry-weight production of as much as 23 percent (fig. 2C). The reasons for the decline in production from fertilized and mulched subplots are not completely known. However, results of soils analyses indicate that these subplots are reacidifying more rapidly than other irrigated sub-

plots. Reacidification, aside from the obvious effect on pH, is accompanied by increases in the solubility of metal ions in the soil solution and changes in plant nutrient availability (Nielson and Peterson 1972). These changes, and probably others, are thought to be involved with the production decline during the second growing season. Work now in progress should help to clarify the adverse influences of reacidification.

The following points result from an analysis of dry-weight production data:

1. The difference in production due to seed mixture was significant; the native plants produced significantly less weight than the other two mixtures.

2. Mulch and fertilizer interact in such a way that mulch had a significant effect only on fertilized plots. On unfertilized plots, mulch had no effect.

3. Fertilizer increased the production of all three grass mixtures. Fertilizer benefits were in the following order: introduced species > native + introduced species > native species.

Plant Cover

Due to the relation between soil erosion and acid production on waste piles, soil erosion on mining disturbances associated with sulphide minerals merits special consideration. Since acid soils and acid drainage water both result from the oxidation of sulphide minerals located on or near the soil surface, the stability of surface materials is a major influence on acid production. If erosion is continually exposing new, unoxidized materials, the processes of sulphide oxidation and soil erosion form a positive feedback cycle that tends to perpetuate high rates of acid production (Ohio State University 1971).

The effectiveness of vegetation in reducing soil erosion is well known. The canopy protects the surface materials from raindrop impact and consequent detachment of soil particles. Vegetation also reduces the velocity of surface runoff, which reduces the cutting action of water and its ability to carry soil particles. Vegetative root systems effectively improve soil structure and porosity. The entire vegetative system moderates the microclimate and provides cover and nutrient sources for beneficial microfauna and flora. Finally, plant transpiration dries the surface and retards the upward movement and surface deposition of soil salts.

Due to differences in plant morphology, soil-erosion control is rarely related to the dry-weight production of vegetation. Ground cover density is a better parameter than production for estimating erosion control (Packer 1951; Meeuwig 1971). Photographic techniques were used to obtain ground cover density estimates for each of the 144 subplots on the Blackbird Mine. These density estimates were then regressed against the clipped and measured weight of vegetation. The simple regression equation is:

$$\hat{Y} = 8.88 + 1.62(X)$$

where:

$\hat{Y}$ = aerial ground cover density, percent

X = vegetation, dry weight (grams) per 2 square feet; $X \leq 56.25$

The standard error of estimate and coefficient of determination (r^2) are 7.8 and 92 percent, respectively. Average ground cover density for each series of four treatment replications is shown in table 5.

Table 5.--*Average ground cover density, percent, for three series of four treatments, by main plots*

Treatment code	Ground cover density, percent		
	Control plot	Topdressed plot	Irrigated plot
N-F-M	18	39	25
N-F-NM	13	29	15
N-NF-M	12	11	11
N-NF-NM	11	8	13
P-F-M	25	83	44
P-F-NM	14	72	18
P-NF-M	12	11	13
P-NF-NM	11	12	12
NP-F-M	20	76	44
NP-F-NM	14	78	16
NP-NF-M	12	13	13
NP-NF-NM	11	12	12

N = native species mixture
P = introduced pasture grass mixture
NP = native + introduced species mixture
F = fertilized
NF = not fertilized
M = mulch
NM = not mulched

Evaluation of Treatments

To facilitate evaluation of treatments, vegetation yield means were grouped by seed mixture and ranked by treatment, table 6. This grouping combines the results from control, irrigated, and topdressed plots and is useful for making comparisons among the treatments for each seed mixture. Regardless of seed mixture, the two greatest yields occurred on fertilized topdressed plots. For all seed mixtures, the fertilized and mulched irrigated plots ranked third. Third and fourth ranked treatments were widely separated. In fact, for each species mixture, the fourth ranking treatment was so poor that it is probably safe to ignore treatment numbers 4 through 12 as potential revegetation alternatives. This idea is supported by the data in table 5, which shows that 25 percent is the greatest average ground cover density of any fourth ranking treatment. This is not sufficient ground cover to protect the soil surface from accelerated water erosion. However, these vegetative stands are only 2 years old and the progress of all treatments will be followed for several more years.

At this time, topdressing with native top soils and subsoils appears to offer the best chance for the successful revegetation of waste piles of the Blackbird Mine. Fertilizer also appears to be a requirement for successful revegetation. On unfertilized subplots, ground cover averaged 12 percent at most. Whether or not a mulching treatment is required, especially on topdressed plots, is not known; however, mulch does not appear to be required.

Table 6.--*Average dry-weight vegetative production by treatment, ranked within seed mixtures*

Rank	Native species		Introduced species		Native + introduced species	
	Treatment	Dry weight lb/acre	Treatment	Dry weight lb/acre	Treatment	Dry weight lb/acre
1	T-F-M	886	T-F-M	2,206	T-F-NM	2,190
2	T-F-NM	598	T-F-NM	1,859	T-F-M	1,978
3	I-F-M	490	I-F-M	1,037	I-F-M	1,039
4	C-F-M	271	C-F-M	463	C-F-M	333
5	I-F-NM	186	I-F-NM	281	T-NF-NM	211
6	I-NF-NM	111	C-F-NM	140	I-F-NM	210
7	C-F-NM	109	I-NF-M	118	C-F-NM	146
8	C-NF-M	89	T-NF-NM	107	T-NF-M	114
9	I-NF-M	72	I-NF-NM	103	I-NF-M	111
10	C-NF-NM	71	C-NF-M	96	I-NF-NM	107
11	T-NF-M	65	C-NF-NM	79	C-NF-M	97
12	T-NF-NM	47	T-NF-M	77	C-NF-NM	79

T = topdressed main plot
C = control main plot
I = irrigated main plot

F = fertilized
NF = not fertilized
M = mulched
NM = not mulched

Species Evaluation

Clearly, those seed mixtures that contain introduced grasses are producing more vegetation than the native mixture (fig. 2 and table 6). However, several items must be considered beyond dry-weight production, including the long-term ability to survive adverse conditions of soils, climate, insects, and diseases. Definitive species evaluation will take longer than 2 years. However, several interesting and informative trends are apparent.

On all subplots in both 1973 and 1974, estimates of plant density, by species, were obtained from subsamples of each subplot. These data are tabulated in table 7. On the better vegetated subplots, plant densities generally decreased from 1973 to 1974; however, vegetative production usually increased as individual plants grew larger and more vigorous. Also, species diversity generally decreased, as less well-adapted species die out. Some subplots that were essentially bare in 1973 exhibited low plant densities in 1974. However, vegetation production was also low.

Among the native species mixture, squirreltail *(Sitanion hystrix)*, western yarrow, and cheatgrass *(Bromus tectorum)* appear to be dominant. Interestingly, hairgrass does not appear on the native mixture plots, but it does appear on the plots of mixed introduced and native species. Hairgrass apparently does not compete well against other pioneer plants indigenous to the Blackbird Mine area. Western yarrow has a high propensity to survive adverse soil chemistry and nutrient conditions, with or without supplemental irrigation.

Among the introduced species, orchardgrass *(Dactylis glomarata)*, timothy *(Phleum pratense)*, and smooth brome *(Bromus inermis)* appear to be dominant, with small admixtures of meadow foxtail *(Alopecurus pratensis)*. Orchardgrass apparently can survive adverse soil chemistry better than the other species. Wheatgrasses are not surviving well and probably will be lost in spite of a good start in 1973.

Table 7.--*Species composition and species density per square foot by years (1973 and 1974), and treatment on each main plot*

Treatment code[1]	1973						1974					
	Control		Topsoil		Water		Control		Topsoil		Water	
	Species	Density	Species	Density	Species	Density	Species	Density	Species	Density	Species	Density
N-F-M	Wheatgrass	5.38	Wheatgrass	6.00	Wheatgrass	3.25	Squirreltail	2.25	Squirreltail	5.50	Yarrow	2.13
	Squirreltail	3.88	Yarrow	2.25	Squirreltail	2.25	Yarrow	1.50	Yarrow	4.38	Squirreltail	1.38
	Cheatgrass	.75	Squirreltail	2.00	Yarrow	2.25			Wheatgrass	1.13		
	Yarrow	.50	Cheatgrass	2.00	Cheatgrass	1.50						
N-F-NM	None*		Wheatgrass	5.00	Wheatgrass	2.75	Squirreltail	1.88	Squirreltail	4.25	Squirreltail	1.75
			Squirreltail	2.75	Squirreltail	1.88	Yarrow	.25	Yarrow	2.50	Yarrow	.75
			Wheatgrass	1.75	Cheatgrass	.63			Wheatgrass	2.38		
			Yarrow	.63	Yarrow	.63						
N-NF-M	None*		None*		Yarrow	0.63	Yarrow	0.88	Yarrow	1.63	Yarrow	1.88
							Cheatgrass	.50	Cheatgrass	.25		
N-NF-NM	None*		None*		Yarrow	1.25	Yarrow	1.50	Yarrow	1.25	Yarrow	1.38
							Cheatgrass	.25	Cheatgrass	.25		
P-F-M	Wheatgrass	4.88	Timothy	13.25	Timothy	8.25	Timothy	3.38	Timothy	11.63	Smoothbrome	5.38
	Orchardgrass	3.50	Wheatgrass	5.75	Wheatgrass	3.50	Smooth brome	3.00	Smooth brome	3.13	Timothy	3.63
	Timothy	3.13	Orchardgrass	3.88	Orchardgrass	2.69	Orchardgrass	.63	Meadow foxtail	1.75	Meadow foxtail	1.50
	Alta fescue	1.25	Smooth brome	1.25	Smooth brome	.63	Meadow foxtail	.25			Alta fescue	.38
	Smooth brome	.25	Alta fescue	.50	Alta fescue	.63						
					Meadow foxtail	.38						
P-F-NM	Timothy	0.50	Timothy	8.00	Timothy	2.13	Smooth brome	0.38	Orchardgrass	14.25	Orchardgrass	0.75
	Alta fescue	.50	Orchardgrass	7.63	Wheatgrass	1.63	Meadow foxtail	.38	Timothy	7.88	Meadow foxtail	.75
	Wheatgrass	.25	Wheatgrass	5.75	Orchardgrass	.88			Smooth brome	1.88	Timothy	.50
			Smooth brome	1.63	Alta fescue	.50			Meadow foxtail	.75	Smooth brome	.38
			Alta fescue	.75	Smooth brome	.38						
			Meadow foxtail	.25								
P-NF-M	None*		Orchardgrass	3.00	None*		None*		Orchardgrass	3.38	None*	
P-NF-NM	None*		None*		None*		Orchardgrass	0.50	Orchardgrass	1.75	None*	
NP-F-M	Orchardgrass	6.63	Timothy	9.38	Wheatgrass	4.50	Smooth brome	1.00	Timothy	13.00	Smooth brome	4.00
	Wheatgrass	5.75	Wheatgrass	6.38	Orchardgrass	3.75	Orchardgrass	.38	Orchardgrass	12.13	Orchardgrass	1.75
	Timothy	3.00	Orchardgrass	5.38	Hairgrass	1.50	Timothy	.38	Smooth brome	3.00	Timothy	1.50
	Hairgrass	1.13	Smooth brome	1.00	Smooth brome	.75			Wheatgrass	1.75	Wheatgrass	.75
	Smooth brome	.50										
NP-F-NM	Wheatgrass	2.50	Orchardgrass	10.50	Wheatgrass	4.88	None*		Orchardgrass	11.00	Smooth brome	0.50
	Orchardgrass	.63	Wheatgrass	7.00	Orchardgrass	3.00			Timothy	9.63	Hairgrass	.50
	Smooth brome	.25	Timothy	6.88	Timothy	1.38			Wheatgrass	2.38	Yarrow	.50
			Smooth brome	1.13	Smooth brome	.63			Smooth brome	1.88	Timothy	.38
			Hairgrass	.63								
NP-NF-M	None*		None*		None*		Orchardgrass	0.75	Orchardgrass	4.50	Hairgrass	0.38
									Hairgrass	1.13		
NP-NF-NM	None*		None*		Hairgrass	0.38	Hairgrass	1.38	Orchardgrass	1.75	Hairgrass	1.63
									Hairgrass	.25	Squirreltail	.88

[1]See table 5 for code identification.
*Densities less than 0.25/ft^2 are not shown.

With data covering only two growing seasons, it appears that orchardgrass, timothy, and smooth brome will produce good grass stands, especially on areas topdressed and fertilized. However, it would probably be a serious mistake to ignore native pioneer species, in spite of their lower dry-weight production. Squirreltail, yarrow, cheatgrass, and perhaps hairgrass appear to be capable of survival under the most adverse conditions. A seed mixture comprised of these introduced and native species would be expected to show good production and ground cover under good growing conditions and yet would be capable of producing an adequate stand of vegetation under adverse conditions.

DISCUSSION

This study was designed to test a broad spectrum of potential treatments to determine the minimum combination of different treatments necessary to provide an acceptable plant cover. These results, covering only 2 years, do not conclusively indicate that minimum combination. However, strong trends in the data suggest treatments that may be most acceptable. Topdressing of mining wastes with native topsoils or subsoils to a depth of 8 inches or more, coupled with a fertilization program, appears to be highly desirable. Irrigation of untreated waste piles for the establishment of vegetation is of questionable value, but cannot be completely dismissed as yet. An unanswered question regarding supplemental irrigation involves the effects of stopping irrigation. These plots will not be irrigated in succeeding growing seasons and the effects of irrigation cessation will be studied. Revegetation of raw mining wastes, even with inputs of lime, fertilizer, and mulch, does not appear to be a desirable alternative.

There are no indications that topdressing materials or mining wastes, treated with a liming agent, had significant adverse effects on either seed germination or seedling emergence. However, thorough seedbed preparation and seed packing are essential to ensure hydraulic contact with the soil. These factors should be considered in pilot or large-scale revegetation attempts. Special measures may be required to ensure hydraulic seed contact in rocky waste piles.

Species evaluation work will continue for several more years. The results on irrigated-fertilized-mulched plots will be especially interesting since the 1974 growing season was the last season of supplemental irrigation. The data so far seem to indicate that a mixture of orchardgrass, timothy, smooth brome, squirreltail, western yarrow, cheatgrass, and perhaps hairgrass will produce satisfactory stands across a wide range of soil chemical and nutrient conditions. In a somewhat oversimplified view, the introduced grasses will produce good stands under the best conditions, the native species will provide some cover under adverse conditions, and admixtures of native and introduced species will provide stands across a wide range of intermediate soil conditions. However, even native species have definite, if undefined, limitations. Low-grade ore pockets or dumps that are high in sulphide minerals and salts probably will not support vegetative growth. These phytotoxic materials will have to be buried.

Some important questions that this research is not designed to answer quickly involve the continued use of fertilizers. Whereas initial fertilization appears to be a strict requirement, we do not know how long the effects will last, or if fertilization of revegetated areas will be a continued requirement at periodic intervals. Undoubtedly these answers partly lie in the complex soil chemistry of acid sulphide soils because plant nutrient availability and plant respiration processes are differentially affected by soil pH. These answers are also inextricably tied to land management goals and long-term land use plans. If high quality surface water showing only trace amounts of acidity and heavy metals is required from this area, plant fertilization will probably be required at periodic intervals for a long time. Reduced land management goals will require smaller physical inputs to maintain the system.

Reacidification of the study site is expected to be a problem, although the difficulty or magnitude of the problem has not yet been defined. The study site was limed in 1972 and, by 1974, some subplots showed signs of moderate to strong reacidification, especially those on the irrigated main plot. The grass clumps shown on the lower inside back cover were growing about 24 inches apart, but the grass on the left side was growing on a spot that is strongly reacidifying, with a soil pH of 3.4 in the surface 8 inches. Without reliming this grass would rapidly die. The grass on the right side still shows good growth and root development in a soil with a pH of 5.0. Without reliming, it would also die over a 1- to 2-year period, depending upon the reacidification rate. Results of plant tissue analyses for the grass clumps shown on the inside back cover are reported in table 8. Notice that the content of potassium, iron, copper, and zinc in the plant tissues is much greater on soil with a pH of 3.4 than on soil with a pH of 5.0. The application of fine agricultural limestone is expected to correct the reacidification problem. However, to date, no adverse vegetative effects of reacidification have been detected on the main plot that was topdressed with 8 inches of native topsoils and subsoils.

Table 8.--*Results of plant tissue analyses for plants growing on raw mine spoils that have strongly reacidified (soil pH = 3.4) or moderately reacidified (soil pH = 5.0)*

Element	Soil pH = 3.4			Soil pH = 5.0		
	Shoots	Meristem	Roots	Shoots	Meristem	Roots
Nitrogen	18,000	12,000	NA	11,000	8,400	7,400
Sulfur	3,500	4,600	NA	2,700	2,400	3,200
Phosphorus	3,000	3,200	1,200	2,900	1,600	1,300
Potassium	23,500	10,000	6,800	18,000	6,000	1,700
Magnesium	800	900	1,000	700	900	200
Calcium	5,600	7,200	3,500	6,500	3,500	6,000
Sodium	200	125	115	275	350	137
Iron	265	11,800	11,770	525	2,800	3,200
Manganese	35	46	103	62	18	98
Boron	7	4	1	8	1	5
Copper	70	400	497	28	160	108
Zinc	180	160	44	15	23	60

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Farmer, E. E., B. Z. Richardson, and R. W. Brown
1976. Revegetation of acid mining wastes in central Idaho. USDA For. Serv. Res. Pap. INT-178, 17 p., 5 ref. Intermountain Forest and Range Experiment Station, Ogden, Utah 84401.

The results of 2 years of revegetation research on acid mining wastes in central Idaho are described. Three types of main plots were used, each containing 12 treatments. Treatments are evaluated in terms of both vegetative production and ground cover. Vegetative species are evaluated in terms of their density and persistence under different treatment conditions. Coupled with a fertilization program, topdressing of mining wastes with selected overburden materials appears to be a highly desirable revegetation practice.

OXFORD: 268:41; 237.
KEYWORDS: surface mine revegetation, revegetation research, acid mining wastes, acid mine drainage, waste dump revegetation, regrassing.

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INSIDE BACK COVER, UPPER:

A vertical color infrared photograph of the three revegetation main plots, August 1974. Numbered spots are as follows:

1. The irrigated main plot, with 48 subplots. Irrigation was a definite aid in establishing plant cover. However, it also speeds the reacidification of limed wastes, which is detrimental to the vegetation. See inside back cover, lower, and table 8.

2. The control main plot, with 48 subplots. The degree of vegetative cover is directly related to the intensity of the red color.

3. Topsoiled main plot, with 48 subplots. Fertilized subplots appear red or orange-red, depending upon seed mixture. Brown (nonfertilized) and light-beige (mulched-nonfertilized) subplots contain little vegetation.

4. A salt seep emanating from the base of the upper bench. These whitish salts are severely phytotoxic.

5. An area with relatively high concentrations of metallic salts. The electrical conductivity of these soils is about 8,000 μmhos/cm., and contain high concentrations of heavy metals. For instance, see table 4, sample 7.

INSIDE BACK, LOWER:

Grass clumps growing on mine spoils show the effects of reacidification of spoil material. The grass on the left grew on a spot that was strongly reacidifying, with a soil pH of 3.4. The grass on the right grew 24 inches away in a soil with a pH of 5.0. If the study site is not relimed, both grasses will die. Yellow leaf parts are necrotic areas; the extent of necrosis depends upon the reacidification rate and degree.

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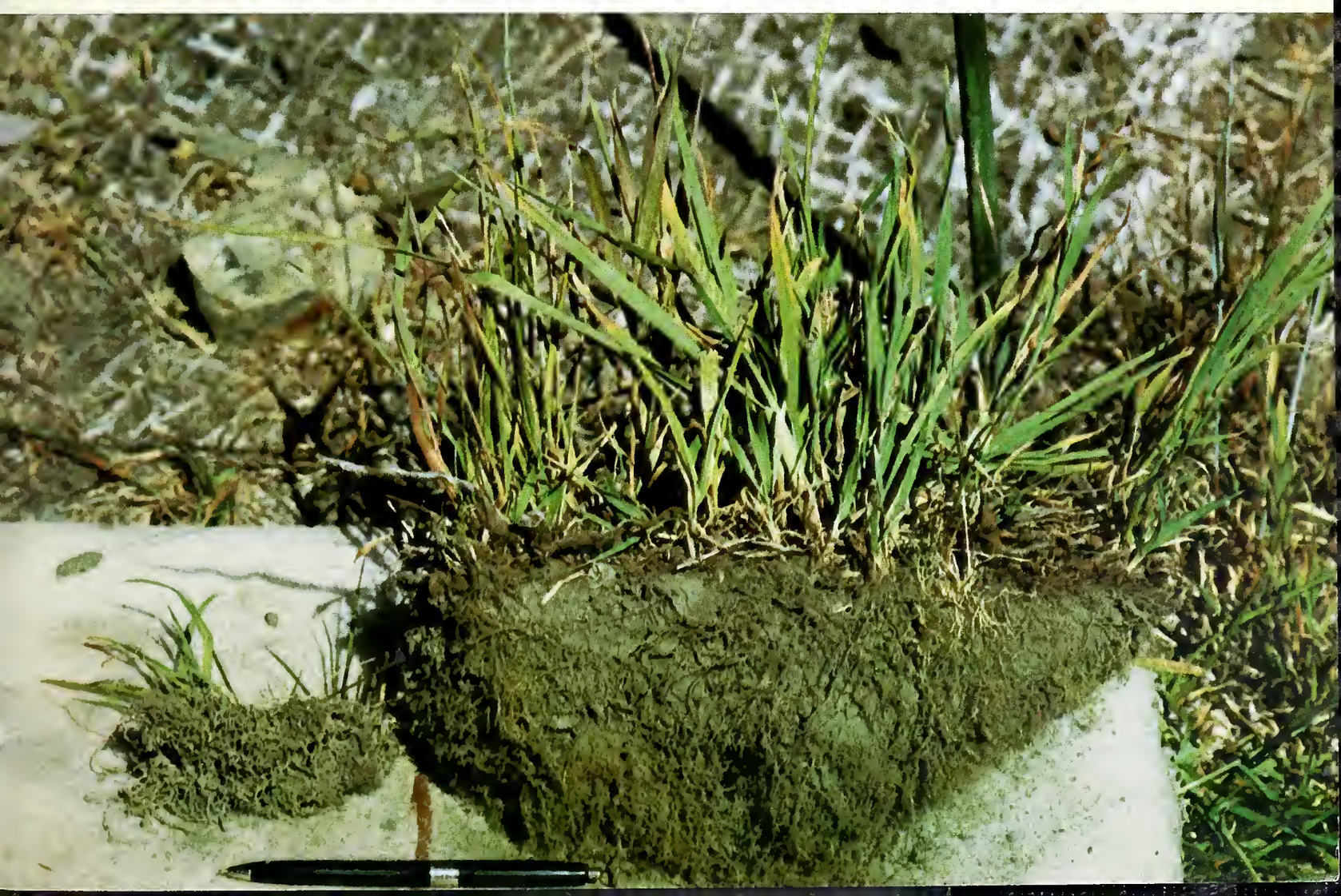

Vegetative assessment work on the copper-cobalt Blackbird Mine, September 1974. Each subplot occupies an 8- by 8-foot area, indicated by the patchwork appearance of different treatments. Some of the treatments have yielded good stands of grass. The left background shows an untreated portion of the waste dump that contains low-grade ores. See table 4, sample 4, for analysis.

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